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A BALLOON MEASUREMENT OF OZONE NEAR SUNRISE

By

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ABSTRACT

The rocket-borne ozonesonde developed at the Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico, was modified to include a constant-volume sampling pump in place of the reservoir. Two such instruments along with other sensors were launched on a 30.3 million cubic foot balloon on 23 September, 1969 from White Sands Missile Range (33° N, 106° 30' W). The data were continuously obtained as the balloon ascended through the stratosphere and floated near 46 km at the time of sunrise. The marked decrease in the ozone concentration at sunrise occurred very rapidly, and there was almost no effect of the scattered radiation at this altitude during the pre-sunrise time. The ozone concentration measured before sunrise near 45 km was 1.5×10^{-3} cm NTP km^{-1} as compared to 1.1×10^{-3} cm NTP km^{-1} measured during the daytime by earlier spectrometric methods.

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INTRODUCTION

Ozone is not distributed uniformly in the atmosphere. The maximum concentration occurs in the lower stratosphere. Presently its distribution is monitored routinely by balloonsondes (1,2) up to the 30-35 km altitude level. Observations above this level are rare. Total ozone measurements are made from ground-based stations with the aid of Dobson's spectrophotometer, and this instrument is also utilized in determining ozone distribution above the balloon altitude levels.

A rocket-borne ozonesonde capable of monitoring the ozone concentration from 65 km altitude to the tropopause level was recently developed (3). Ozone is detected by the chemiluminescence process as the instrument descends on a parachute. This rocket-borne ozonesonde has been modified to include a constant-volume sampling pump and in September 1968 was flown on a large balloon which floated near 48 km altitude (4). Two similar instruments, along with other sensors, were launched on a 30.3 million cubic foot balloon from White Sands Missile Range on 23 September 1969.

INSTRUMENT

A constant-volume sampling pump, made of Teflon, replaced the reservoir incorporated in the self-pumping feature of the rocket-borne ozonesonde (Figure 1). The power supply and telemetry system were common to all the sensors, which were mounted on a hexagonal frame, with the battery pack in the center. The ozonesondes were insulated with plastic foam because of the low temperatures (-70°C) to which they would be subjected during balloon ascent. Additional care was taken to avoid the cold temperature effect by providing electric heaters around the photomultiplier tubes. The data from the ozonesondes were transmitted on a 1680 MHz carrier frequency on a time-shared basis with the other sensors, providing half a minute of data every four minutes.

EXPERIMENT

The balloon was launched at 0636 UT (Universal Time) from Pony Site (33° N, 106° 30' W), White Sands Missile Range, New Mexico on 23 September, 1969, and tracked by AN/FPS-16 radar. In addition to two ozonesondes, there were instruments to measure temperature, pressure

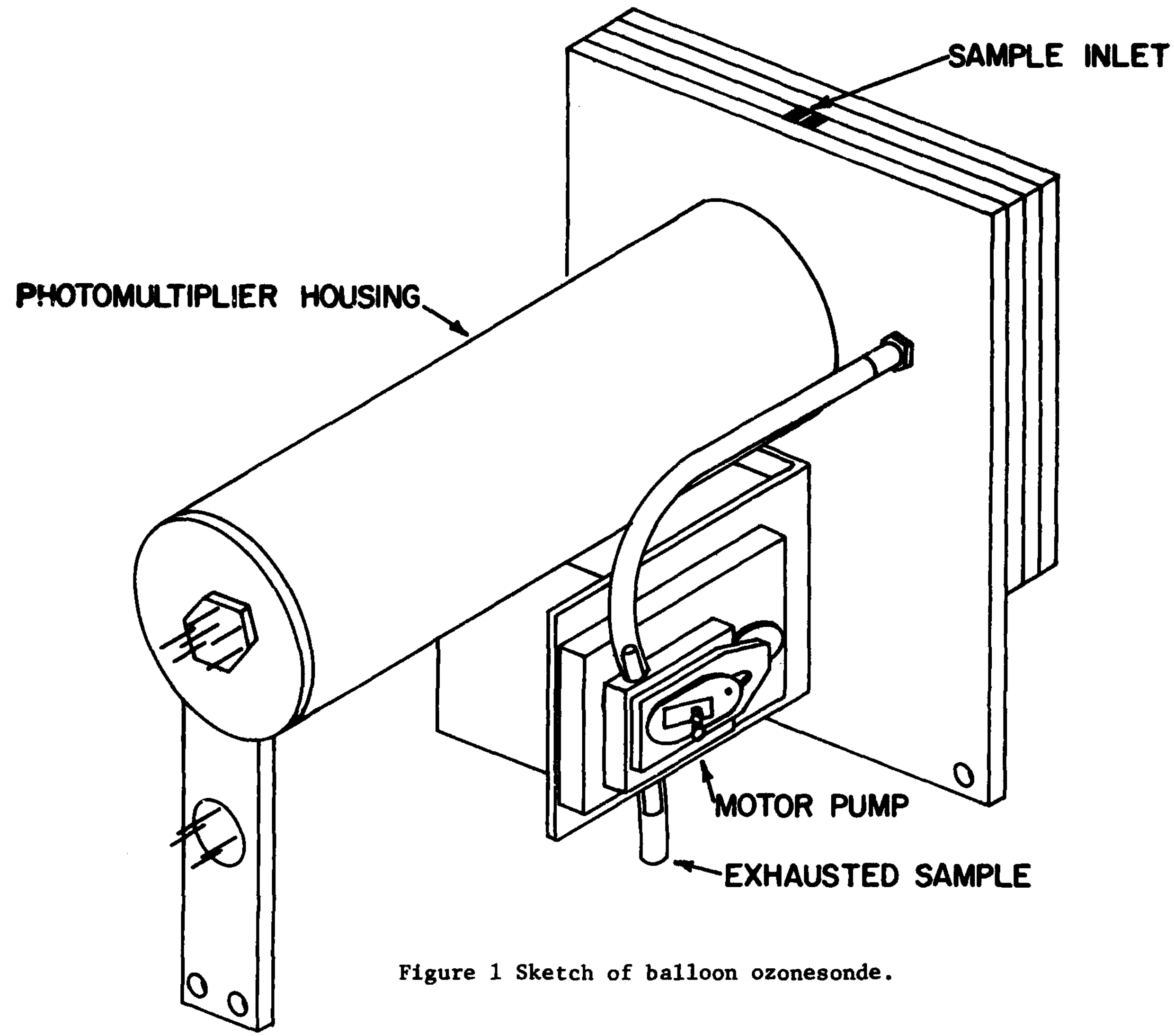

Figure 1 Sketch of balloon ozonesonde.

and density. The balloon was slow in ascent, taking nearly six hours to reach an altitude of 46 km at the time of sunrise. A Mast electrochemical ozonesonde was also released at 1600 UT from the Small Missile Range (32° 30' N, 106° 25' W).

RESULTS AND DISCUSSION

The data received from launch to sunrise as the balloon floated above the Missile Range are presented in Figure 2. One ozonesonde stopped functioning at 29 km and the other experienced a solar radiation leak after sunrise. Data obtained from the Mast electrochemical ozonesonde are presented in Figure 3. Sunrise on the balloon occurred near 1225 UT at an altitude of approximately 46 km. The effect on the ozone concentration is shown in Figure 4.

No measurements of the total amount of atmospheric ozone above the site were made with Dobson's spectrophotometer, but the integrated ozone obtained from this profile (318 m - atm - cm) is in agreement with the total ozone (311.6 m - atm - cm) measured at Boulder (40° N) at local noon on that day (5).

The reduction of ozone at the incidence of solar radiation at sunrise can be explained by the following reaction

$$O_3 + h\nu \rightarrow O + O_2 \qquad \lambda < 11400\ \text{Å} \tag{1}$$

This includes both $O(^3P)$ and $O(^1D)$ production. The atomic oxygen thus formed may combine with moleculer oxygen for the production of ozone,

$$O + O_2 + M \rightarrow O_3 + M \tag{2}$$

or may undergo some of the following reactions (6,7),

$$OH + O(^3P) \rightarrow O_2 + H \tag{3}$$

$$HO_2 + O(^3P) \rightarrow OH + O_2 \tag{4}$$

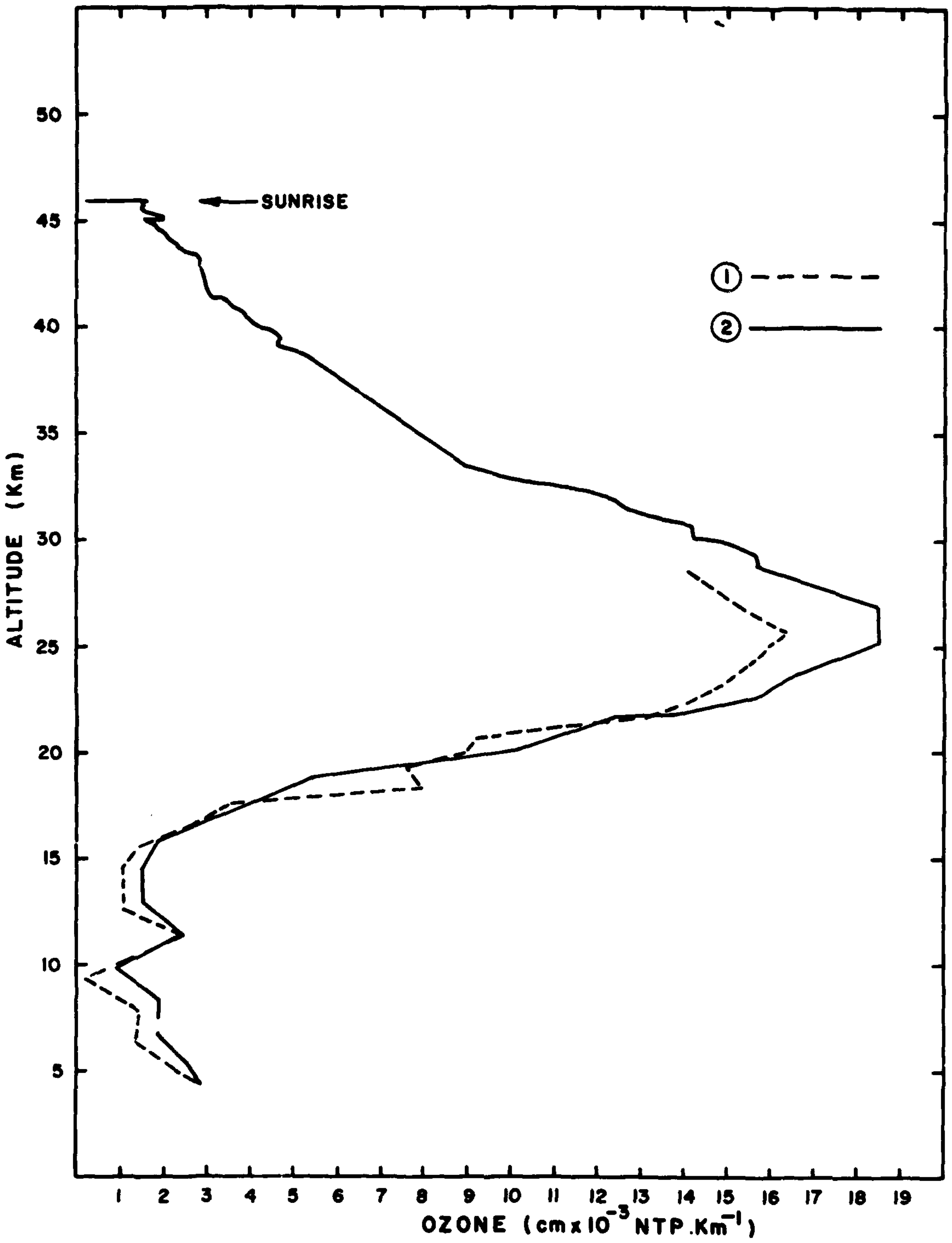

Figure 2 Ozone concentration versus altitude as measured over White Sands Missile Range on 23 September 1969.

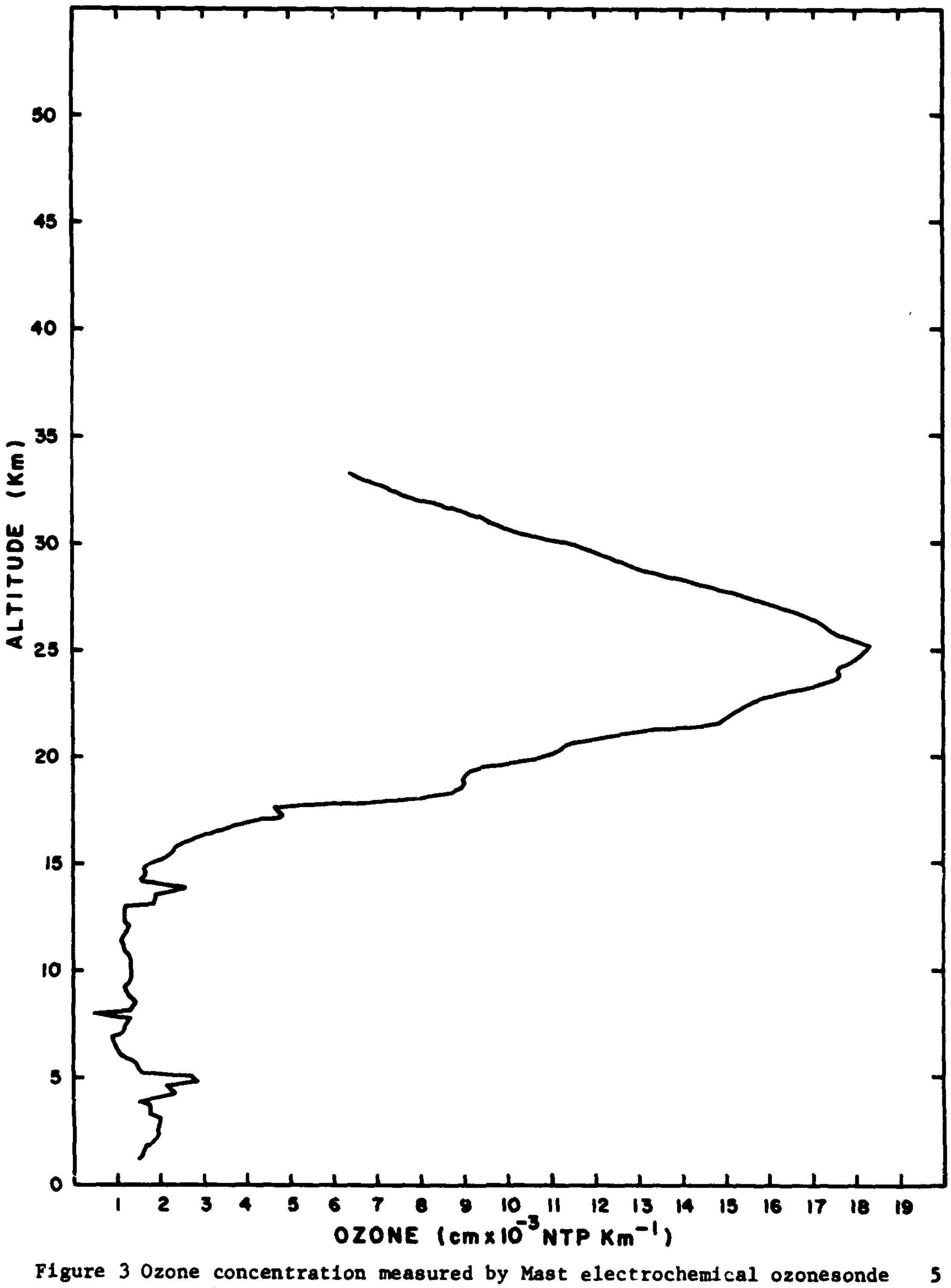

Figure 3 Ozone concentration measured by Mast electrochemical ozonesonde over White Sands Missile Range on 23 September 1969.

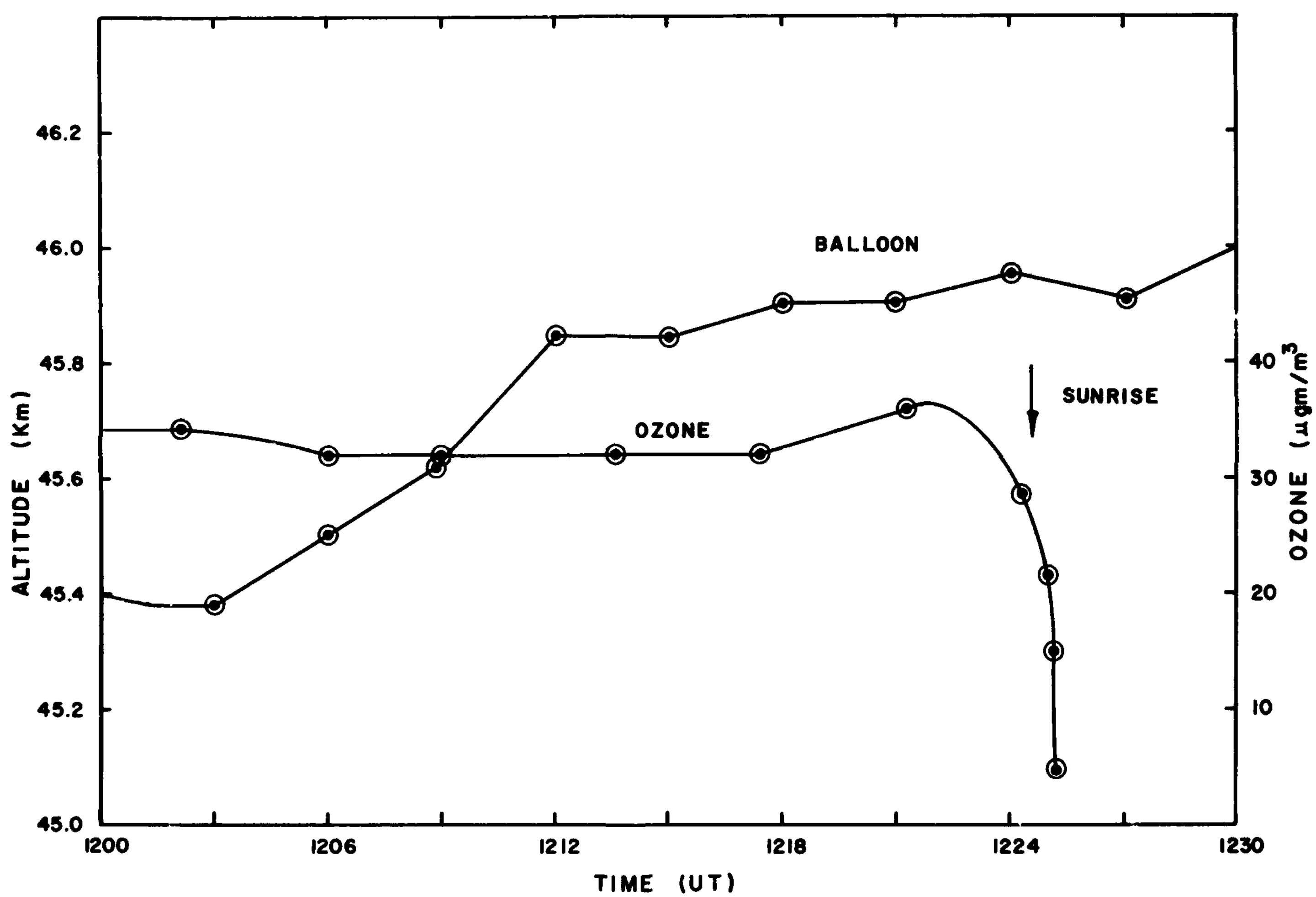

Figure 4 Sunrise effect on ozone distribution.

$$H + O_2 + M \rightarrow HO_2 + M \quad (5)$$

$$O(^1D) + M \rightarrow O(^3P) + M \quad (6)$$

where M is the oxygen or nitrogen molecule.

The equilibrium concentrations at 45 km altitude during daytime for an oxygen-hydrogen atmosphere of OH, HO_2, H, $O(^3P)$ and $O(^1D)$ as calculated by Hunt (6) are, respectively, 5×10^7, 10^8, 5×10^5, 10^{10} and 5×10^4 molecules per cubic centimeter. The predawn concentrations of these constituents vary quite substantially from the daytime concentrations. For example, $O(^3P)$, H and $O(^1D)$ disappear below 50 km, whereas OH decreases by more than two orders of magnitude and HO_2 by more than one order of magnitude.

Reactions (3), (4) and (6) are faster than (2) and (5). At sunrise, atomic oxygen $[O(^3P), O(^1D)]$ released by reaction (1) may be absorbed by OH and HO_2 instead of revamping the ozone concentration by reaction (2). This results in lower ozone concentration at sunrise than the equilibrium value during the daytime.

The results (Figure 4) show that the ozone concentration remained constant when the balloon was floating between 45 and 46 km altitude before sunrise. The concentration started decreasing approximately one minute before the sun's rays actually were incident upon the balloon at 1225 UT. The change of ozone concentration was nearly instantaneous, the ozone decreasing to almost zero in about twenty seconds. A malfunction (light leak) occurred as the instrument started to detect variations in the ozone concentration.

The data obtained from the balloon as it rose through the troposphere and into the stratosphere are in agreement with the data obtained by the Mast electrochemical ozonesonde. The concentration measured between 45 and 46 km altitude during the predawn hours is 1.5×10^{-3} cm NTP km^{-1} as compared to 1.1×10^{-3} cm NTP km^{-1} measured during daytime (8). The uncertainty in these observations is estimated to be $\pm$ 5%. This was the first time a sunrise-related decrease in ozone has been recorded from a stable platform at this level.

CONCLUSIONS

The ozone concentration obtained through the predawn hours at 45 km shows slightly higher values than that recorded during daytime by other methods. The concentration decreased very rapidly as the sun's rays were incident upon the balloon. There was almost no effect of the scattered radiation at this altitude before sunrise.

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13. ABSTRACT

The rocket-borne ozonesonde developed at the Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico, was modified to include a constant-volume sampling pump in place of the reservoir. Two such instruments along with other sensors were launched on a 30.3 million cubic foot balloon on 23 September, 1969 from White Sands Missile Range (33°N, 106° 30'W). The data were continuously obtained as the balloon ascended through the stratosphere and floated near 46 km at the time of sunrise. The marked decrease in the ozone concentration at sunrise occurred very rapidly, and there was almost no effect of the scattered radiation at this altitude during the pre-sunrise time. The ozone concentration measured before sunrise near 45 km was 1.5×10^{-3} cm NTP km^{-1} as compared to 1.1×10^{-3} cm NTP km^{-1} measured during the daytime by earlier spectrometric methods.

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